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ABSTRACT

This paper traces the concept of complexity as it has been employed in empirical investigations of organizations over the last decade, presents a brief description of a doctoral dissertation in which complexity was one of the key variables, and then offers some summary comments on the utility of the complexity variable for school analysis. (Author)

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Complexity as a Dimension of the School's Technical System

W. W. Charters, Jr.

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Center for the
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COMPLEXITY AS A DIMENSION OF THE SCHOOL'S TECHNICAL SYSTEM

A WORKING PAPER

W. W. Charters, Jr.

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"Complexity" of an organization's technical system has been a popular variable in organizational analysis in the last decade and seems to hold promise for an examination of the school's work structure. On the broad scale of organization technologies, of course, the educative process is very simple. Nevertheless, certain instructional innovations have the effect of making the school's technical system more complicated, in some sense of the term, and of casting the direct workers (i.e., the teachers) in new relationships with one another.

In this paper, we will trace the concept of complexity as it has been employed in empirical investigations of organizations over the last decade, present a brief description of a doctoral dissertation in which complexity was one of the key variables (Keene, 1962), and then offer some comments of our own on the utility of the complexity variable for school analysis.

Complexity from Udy to Hall

Udy, (1959), the first investigator to give operational meaning to technological complexity, was concerned with the effect of an organization's technology on hierarchical authority structure. He proposed that complex technologies create numerous authority levels. His reasoning was a modification on the old "span of control" idea; he sought to account for height of authority pyramids on the grounds that supervisory personnel could oversee only a given number of people--five was often taken as a handy number--and, hence, as

organizations grew in size, the number of supervisors and super-supervisors had to increase accordingly. Udy argued, however, that a supervisor is limited not by the number of people under his jurisdiction but by the number of work operations to which he can attend at once. More complicated work operations, even with a constant number of workers, require larger numbers of supervisors. Supervisory attention was the intervening variable linking complexity with the dependent variable of Udy's study, number of authority levels.

Udy measured technological complexity (the number of work operations requiring attention, A) in the following terms:

$$A = t + s + c + 1,$$

where t is the total number of tasks in an organization, s the maximum number of specialized operations ever performed at one time, and c the presence (1) or absence (0) of combined effort. This was admittedly a crude measure, especially in light of the fact that he applied it to organizations in non-industrial societies whose records he gleaned from the Yale Human Relations Area files, but he was able to show that organizations with "A" scores greater than five had more levels of authority than organizations with "A" scores of five or less. For our purposes, the useful feature of Udy's work is his formulation of how complexity affects the supervisory task.

In Anderson and Markov's (1961) study of the relationship of complexity to the proportional size of the administrative cadre in Veterans Administration hospitals, the intervening variable was extended to the broader concept, coordination. In this work, as in Rushing's (1967) later research on the same problem, increasing complexity of an organization's technical process was said to increase problems of coordinating work. In the view of these authors, coordination is effected mainly by administrators; thus increments in complexity entail increments in the number of administrators.

Δ complexity $\longrightarrow$ Δ coordination problems $\longrightarrow$ Δ no. administrators

Anderson and Markov did not elaborate on the meaning of coordination. Indeed, they relied on Udy's formulation in justifying their operational specification that General Medical and Surgical hospitals (GMS) were "more complex" than Tuberculosis (TB) hospitals. After citing Udy, they simply pointed to the fact that GMS hospitals performed all of the tasks that were performed in TB hospitals and other tasks as well, thus had a larger value for t.

Anderson and Markov had addressed their study to the finding of Terrien and Mills (1955) that the size of the administrative component in school systems increased disproportionately faster than the total size of the systems. They believed the complexity variable could account for this relationship, at least in part. This turned out to be approximately true in the 49 hospitals they studied. Holding total size more or less constant,¹ the more complex GMS hospitals had proportionately greater numbers of administrators than the TB hospitals. Within hospital type (i.e., complexity constant), organizational size was indifferently related to relative size of the administrative component.

Anderson and Markov attempted to reconcile their findings and those of Terrien and Mills by introducing another determinant of the number of administrators in an organization: viz, the number of geographical locations at which work is carried out. They suggested that increases in the total size of school systems, unlike hospitals, is typically accompanied by increases in the number of geographical dispersion of sub-units; more locations means proportionately more administrators. Thus, total size would show a positive relationship with proportions of administrators in school systems but not in the Veterans

¹ GMS hospitals were generally much larger than TB hospitals, and the investigators' attempt to control for size between them was extremely rough.

Administration hospitals, which were located in one place. Technological complexity, however, remains as a separate, independent determinant of size of the administrative cadre in their scheme.

Rushing (1967) followed the same line of reasoning as Anderson and Markov in investigating what he called the "complexity-administrative growth hypothesis," except that complexity came to refer specifically to the division of labor. Rushing wrote,

The hypothesis is a straightforward deduction from two assumptions: (1) that increases in the division of labor lead to increases in problems of coordination, and (2) that administrative personnel, rather than production personnel, are the ones primarily concerned with problems of coordination (p. 275).

His study of total organizational size and complexity in 41 industrial categories showed the effects of the two variables on proportional size of the administrative component to be independent and opposing. He found that the greater the complexity in the division of labor, but the smaller the number of production personnel, the greater the relative proportion of administrators.

Rushing's definition of complexity in terms of the division of labor rather than of work processes, per se, was in the spirit of Hage and Aiken (Hage, 1965; Hage & Aiken, 1967a, 1967b; Aiken & Hage, 1968). These writers considered functional complexity to mean degree of occupational specialization. Hage (1965) defined complexity operationally as (1) the number of occupational specialties in an organization and (2) the length of training required for each. In Hage and Aiken's studies of social welfare and health organizations, a third indicator of complexity was added: the extent of professional activity of the specialists, such as belonging to and attending meetings of professional associations. Rushing broke with Hage and Aiken, however, by preferring to measure complexity in terms of the distribution of specialties in an organization

rather than in terms of the number of specialties, and he ignored the training attribute. His index, $\underline{D}$, increases the more evenly personnel are distributed across occupational classifications

$$\underline{D} = \frac{(\sum X_i)^2 - \sum X_i^2}{(\sum X_i)^2},$$

where X_i is the number of persons in the i^{th} occupation (Rushing, 1968). Since the maximum value $\underline{D}$ can achieve is a function of the total number of occupational classifications in an organization, Rushing regarded it advisable to remove from the index all contributions to its value made by number of occupations. He did this by dividing $\underline{D}$ by $\underline{D}_{\text{max}}$, the latter calculated by,

$$\underline{D}_{\text{max}} = 1 - 1/n,$$

where n is the number of occupational classifications present in the organization. Rushing offered no theoretical justification for this correction, only a methodological justification that the correction permitted the index value to range between 0 and 1.00. In some sense of complexity, at least, one organization with six or seven occupational classifications could be considered more complex than another containing two or three specialties, even when the distribution of personnel across the classifications is the same.

Hall and his colleagues used complexity to cover substantially more territory (Hall, Haas, & Johnson, 1967a, 1967b).

Complexity . . . is the degree of internal segmentation--the number of separate "parts" of the organization as reflected by the division of labor, number of hierarchical levels, and the spatial dispersion of the organization (1967b, p. 906).

Thus, complexity is an attribute not of work operations but of the total organizational "configuration" (Pugh & Others, 1963); it mixes what Rushing called "structural differentiation" and "individual differentiation," i.e., division

of labor (Rushing, 1967); and it includes as one of its components the "geographical location" variable of Anderson and Warkov (1961). Complexity is, indeed, an omnibus term for Hall, Haas, and Johnson. Recently, Glau (1970) has treated all of these matters systematically under the rubric of differentiation of the social structure, ignoring the "complexity" label altogether.

Five of their 11 indicators of organizational complexity refer to the division of labor component, but all are remote from Hage and Aiken's and Rushing's measures. They include:

1. The number of distinct organizational goals (multiple goals indicating a necessary division of labor beyond that required by a single goal).
2. Presence of more than one major organizational activity.
3. The number of major divisions or departments (horizontal differentiation).
4. The most specialized department (number of distinct subdivisions under major departmental headings).
5. Mean intradepartmental subdivisions (the total number of subdivisions divided by the number of departments) (Hall, Haas, & Johnson, 1967b, p. 906).

It is worth noting that the first indicator in the list is identical to one of Udy's (1959) components of supervisory attention, number of organizational tasks, t.

The Keene Study

For two reasons the little-known study by Keene (1962) deserves our close attention. First, it dealt with differences in complexity within a single class of organization--the public secondary school. Most of the studies cited above were concerned with complexity differentials across a wide spectrum of organization types or even, in Rushing's case, across industries, and the definitions and measurement procedures in them were correspondingly gross. Keene's focus on the school, of course, is especially propitious for our present work.

Second, Keene developed an articulated conceptual scheme that sought to weave a number of key variables together in meaningful strands. It seems that recent investigators of organizations, including Hage and Aiken but more notably Hall and associates (Hall, 1963; Hall & Tittle, 1966; Hall, Haas & Johnson, 1967a, 1967b) and Pugh (Pugh and Others, 1963, 1968, 1969a, 1969b), have lost interest in attempting to specify the mechanisms and processes connecting organizational attributes in favor of constructing taxonomies and seeking relationships among dimensions on strictly empirical grounds. Much of this work, incidentally, has been directed toward demonstrating that "bureaucracy" is not all of one piece. Keene, in contrast, wished to discuss functional relations between variables.

The totality of Keene's thesis is far too broad to present here in all its theoretical and empirical detail. In general, he was concerned with the effects of organizational features of schools on the autonomy, or "operational freedom," of teachers. He saw sets of opposing forces at work in complex organizations whose staffs consist of professionals. On the one hand, there are sociological forces arising from the organizational need for coordination that tend to "standardize" the activities of the professionals, thereby restricting their freedom to make operational choices and limiting their exercise of professional competency. The threatened abrogation of professional competence, on the other hand, gives rise to psychological forces within the individual and social forces within the collegial group to protect the operational freedom of professionals. These opposing forces create a quasi-stationary equilibrium. In small, simple schools the need for coordination and consequent standardization is minimal and, at the same time, the competence and professional identification of the staff is not great; the strength of the opposing forces in the

forcefield are not substantial. As schools grow in size, resources, and complexity, however, both sets of forces increase in strength, and the equilibrium point is characterized by tension and conflict.

Keene studied 12 Illinois high schools in depth, selected to cover four size categories: Small (ADM, 150-225), Transitional (ADM, 550-750), Large (ADM, 1500-1600), and Very Large (ADM, 1800-2800). In each he collected evidence by interview, questionnaire, and documents to measure such things as degree of staff specialization, complexity of the scheme for dividing the instructional workflow, job standardization in four areas of teacher activity, differing in proximity to domains of professional competence, actual competence of the staff, strength of colleague-group norms regarding administrator encroachment on teacher autonomy, and sensed autonomy on the part of teachers. His measurement procedures and data analyses were elaborate and sophisticated.

Concepts

We will confine our summary to the first half of Keene's thesis--the part concerned with the "sociological" forces associated with the organizational need for coordination. The core of his argument here is similar to Anderson and Warkov's and Rushing's: complexity produces coordination needs which are met by organizational mechanisms, such as administrative performance. Need for coordination is an unmeasured hypothetical construct. Keene went beyond these other authors, however, in two respects. For one thing, he viewed complexity as referring to the scheme for dividing the workflow of the school, i.e., the instructional workflow. In essence, he proposed that coordination needs arise whenever a break occurs in the workflow and the "through-put" (students) pass from one direct worker to another or whenever two direct workers are expected to process through-puts identically. Thus, for Keene, coordination was a matter of "fitting together" the work contributions of participants in the

workflow, not a matter of directing or supervising job performance, as it was for Udy, Anderson and Warkov, and Rushing. Keene's conception led him to construct a two-component measure of instructional complexity, as we will describe below, based on an analysis of the high school's workflow.

In another, critical respect Keene differed from other investigators. He proposed that coordination needs are met by two distinct organizational mechanisms, not just by administrators, as usually suggested. Coordination can also be achieved by performance programs. Performance programs, in the sense of March and Simon (1958, pp. 140ff), are predetermined specifications to participants of the activities (means) they are to follow or the product (ends or goals) they are to achieve. Specification of means is especially limiting of professional autonomy, and this aspect of performance programs became one of Keene's key variables--what he called standardization. According to his reasoning, an increment in complexity of dividing an organization's workflow (and, thereby, an increment in need for coordination) produces either more administrative officers or greater standardization or both.

Keene formulated an interesting proposition concerning relationships among complexity, administrative coordination, and coordination by standardization, applicable to high schools, that runs as follows. There is in general a progressive increase in standardization with increasing size and complexity of the school, but when high schools reach a particular size-range, departmentalization typically occurs. Since departmentalization entails the establishment of an administrative officer (i.e., a department chairman), coordination needs are served by the administrator instead of by standardized performance programs and, at that point, standardization declines. As the school's complexity

increases further, however, standardization again increases.² (See Fig. 1.) It was this proposition that accounts for Keene's use of "transitional" to describe the second size-class of high schools he investigated; they are in a band of transition from non-departmental to departmental status.

Apart from his investigation of this hypothesis, however, Keene paid no attention to the effect of size and complexity on the administrative component in the high school. His empirical work was directed principally to the standardization mechanism.

Keene employed a second variable, in addition to complexity in division of labor, said to give rise to need for coordination, viz., specialization. Where most writers treat division of labor and specialization interchangeably, he believed that a given scheme for dividing the workflow may or may not entail specialization on the part of operatives and that, in any event, a high degree of specialization creates coordination problems on its own.³ By specialization, Keene meant the extent to which staff members teach in one subject-area only.⁴ The unique coordination problems posed by specialization grow out of the

²Another interesting distinction is found in Keene's study, relevant to his concern with the effects of coordination mechanism on professional autonomy. Administrative control will be regarded by the professional as less of a threat to his competency when that control is exercised by a like-specialist, such as a chairman of the science department who, like himself, is also a certified science teacher, than when it is exercised by an unlike specialist, such as a principal certificated in, say, social studies. This reasoning is also found in Goss (1961).

³Keene was, in fact, more ambivalent concerning the conceptual status of this variable than our summary would suggest. It was not well integrated into his theoretical system, and we have added some of our own views to his treatment.

⁴We propose a more general definition of specialization in our Note on Specialization, Appendix A.

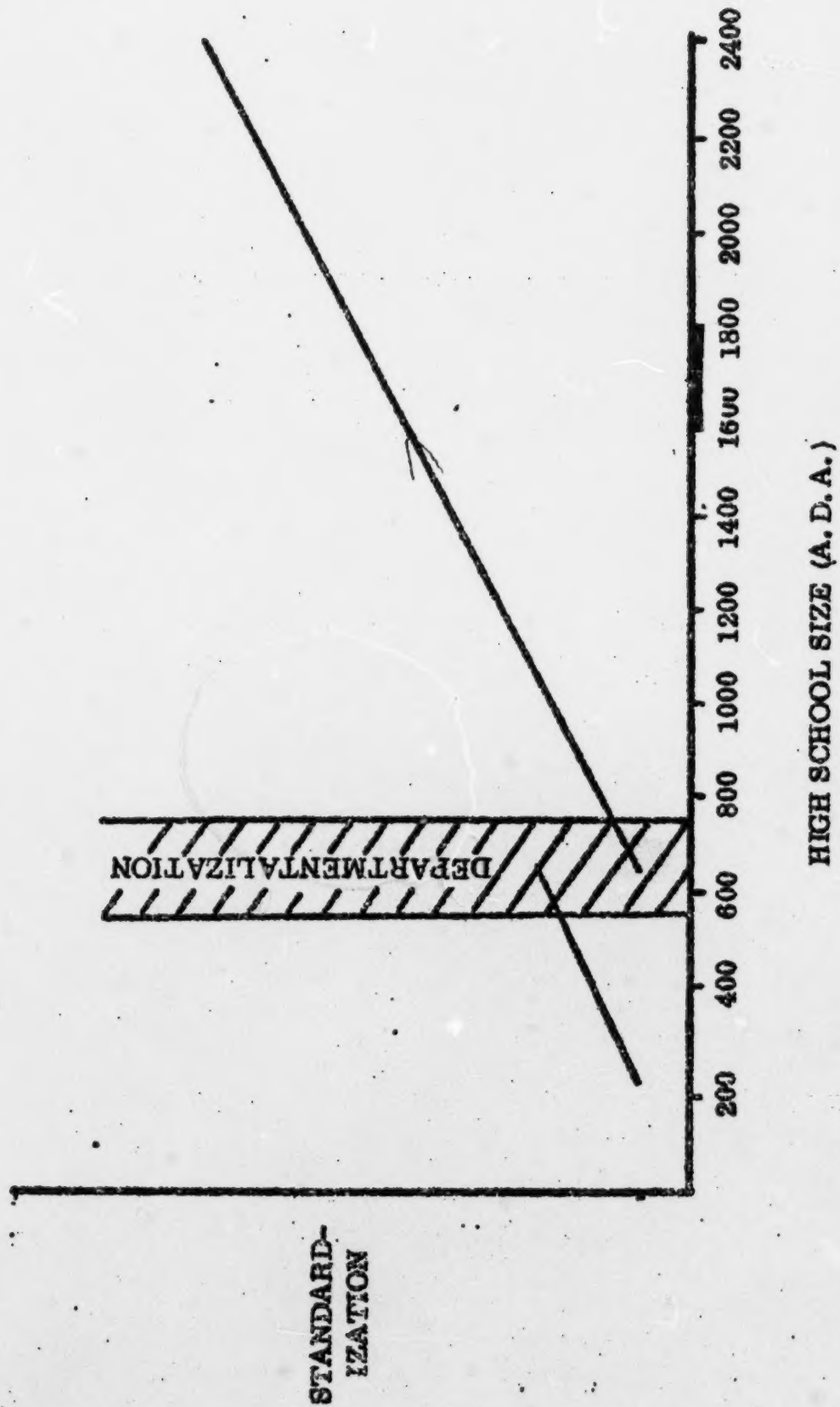


Figure 1. Effects of departmentalization on the relationship between school size (complexity) and standardization in Keene's theory.

"narrowing of perspectives" and "trained incapacity" often remarked as characteristic of experts. Extensive specialization in an organization, thus, would necessitate some mechanism (including the establishment of performance programs) for mitigating the clash between specialized perspectives that might otherwise ensue.

Before describing the measures and some of the findings of the study, we might note the role played by the variable, organization size. While Keene did not offer a close analysis of size, he tended to regard it as carrying little theoretical meaning in its own right. Complexity and specialization were the effective independent variables in his formulations; empirically they happen to correlate with size. His selection of high schools by size was simply a convenient way of choosing organizations likely to vary in complexity and specialization. Tacitly, however, Keene imposed additional meaning on the size variable. He invoked a conception of economy of scale, for example, in recognizing that departmentalization occurs at a particular point in high-school growth. Elsewhere in his study, too, Keene implicitly associated organization size with command over resources, an association that allowed him to understand why larger schools are able to attract teachers with greater professional competence. But, as with most organization analysts of the time (e.g., Tallachi, 1960), the contributions of sheer size to coordination needs was left uninspected by Keene.

We must hasten to point out, however, that in the empirical aspects of his study (as distinct from the conceptual), size assumed prime importance. His descriptive account of the high schools was organized according to size-classes, and the relationships he reported were all tied to size rather than his measure of complexity or specialization.

Figure 2 summarizes briefly the key terms and relationships in the first part of Keene's theory.

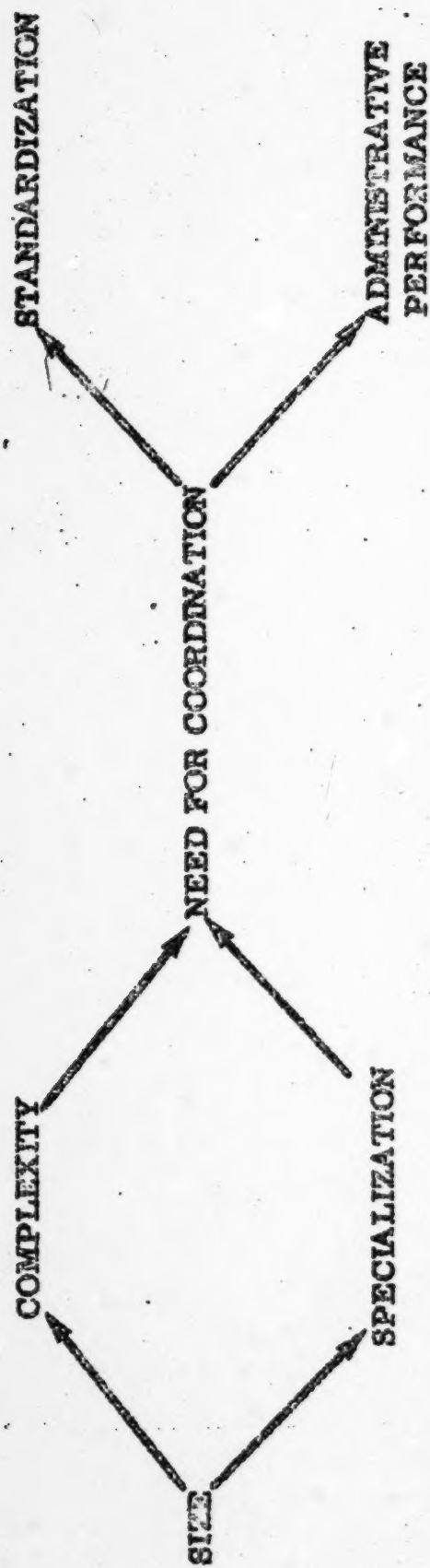


Figure 2. Theoretical relationships among key variables in Keene study.

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Operational Definitions

Size. The measure of school size posed no empirical problems and minor conceptual ones. Keene selected high schools on the basis of Average Daily Attendance (ADA) but also reported size of the teaching faculty. The latter (number of employees) is the more common indicator of an organization's magnitude. It has the advantage of being proximal to the organizational variables size is said to govern, and it is readily comparable across different organizations. But a more distal measure, like ADA or Average Daily Patient Load used in Anderson and Markov's (1961) hospital study, which reflects magnitude of the organization's work load, carries certain advantages: it is truly a more independent variable than number of employees, which can be regarded as an organization's response to work-load size (and a response that schools exercise differentially through teacher-pupil ratio policies); moreover, ADA introduces less arithmetic contamination in relationships with other variables whose measures are ratios containing number of teachers in the denominator. Over a broad enough range, of course, ADA and number of teachers are strongly correlated. We will report Keene's data in terms of ADA.

Complexity. The measure of instructional complexity (or "central" complexity, I_c , as Keene called it) is a multiplicative combination of two indexes.

Instructional complexity arises from the need to coordinate instructional activities simultaneously and sequentially. It may be rather important that the teachers of all the Algebra I sections teach the same thing at the same time so that all students successfully completing this course will have advanced to approximately the same level and will be ready for the next Algebra course regardless of which Algebra I the student may have taken. This is an example of horizontal complexity (p. 38).

The index of horizontal complexity (I_h), then, was taken as the complement of the ratio of the number of sections of courses to the number of different courses in the high school, or,

$$I_h = 1 - \frac{C}{S},$$

where $\underline{C}$ is number of different courses and $\underline{S}$ is number of different sections, including duplicate sections of a given course. The index of vertical complexity ($\underline{I_v}$) concerned the sequential arrangement of instructional activities.

This kind of complexity arises from the necessity to teach one thing before another and occurs within a given course and between courses. The sequential arrangement of units of work within the Algebra I course may be very important because of the cumulative nature of the concepts being developed. It may also be very important that a student take Algebra I before taking Algebra II for the same reason, and that in the Algebra I course he advance through quadratic equations--or to some other specified level--before being considered ready for Algebra II (p. 39).

The index is the complement of the ratio between the number of subject areas and courses taught,

$$\underline{I_v} = 1 - \frac{\underline{SA}}{\underline{C}},$$

where $\underline{SA}$ is the number of different subject areas in the high school and $\underline{C}$, as before, is the number of courses taught in all areas.

Keene believed that "interaction" exists between horizontal and vertical complexity such that "coordination to meet the demands of one type of complexity in the instructional area will, in some instances, simplify the other type of complexity" (p. 39) and that multiplication of the two indexes would appropriately represent "central" complexity. Hence,

$$\underline{I_c} = \underline{I_h} \times \underline{I_v}.$$

$\underline{I_v}$, thus, will be 0 in the simplest high schools offering only one section of each course and one course in each subject area; it will approach 1.00 asymptotically in the most complex schools with many sections per course and many courses per subject area. Values of $\underline{I_v}$ ranged from .09 to .69 in the 12 high schools of his study.

Specialization. The measure of specialization reflects the extent to which faculty members confined their teaching to their own specialty and is a simple index formed by the ratio of the number of teachers teaching in one subject

area only to the total faculty size.

$$I_{sp} = \frac{T_s}{T}$$

where I_{sp} is the index of specialization, T is the number of teachers, and T_s the number teaching in only one subject area. We have included, as Appendix B, Keene's classification of courses by subject area. In developing the classification scheme, he was guided heavily by teacher certification regulations of the Illinois State Office of Public Instruction. The values of this index ranged from .53 to .97.

Not surprisingly, the two indexes, I_c and I_{sp} , are substantially (and linearly) related. Their product-moment correlation is .76 in Keene's data. As we will see shortly, this is probably due to their common dependence on high school size.

Standardization. A large share of Keene's dissertation is devoted to detailed, school-by-school descriptions of procedures for standardizing teaching activities--of specifications of teachers' classroom performance. Much of the burden of demonstrating the relationship between school size and standardization is carried by the descriptive detail, but he also furnished two kinds of more quantitative, summary materials. We should point out, before reporting them, that Keene distinguished four dimensions of classroom performance in which standardization can take place: selection of course content, pupil evaluation, pupil discipline, and obtaining classroom supplies. These are listed in order of increasing peripherality to the domain of professional expertise of teachers, in Keene's view, and were distinguished to test the hypothesis that standardization will be greater in "competency-peripheral" activities than in "competency-central" areas.

One of his summaries showed the incidence in the 12 high schools of the major "standardizing devices used to coordinate instruction." The particular devices are listed in Table 1. In general they refer to any procedure that is likely to circumscribe the teacher's choice of alternatives with respect to selecting course content. In Keene's words, they cover:

(1) what is specified as content, textbooks, curriculum guides, courses of study; (2) who specifies it, to what extent the teachers have a voice or some control over specification; (3) to what extent supplementary materials and extra-classroom resources are specified or permitted; (4) whether and in what manner the teacher is permitted to deviate from specifications; (5) the extent to which the coverage of materials is expected, required, and checked upon; and (6) related practices that make for uniformity of classroom procedure in the matter of instruction and course content, such as visitation of classes, teacher-ratings, and merit provisions in the salary schedule that make visitations critical (p. 150).

It is interesting that embedded in Keene's paragraph are both of the ways distinguished by Hall (1963) and subsequently by Hage and Aiken (1967a) in which formalization by rules and regulations insure predictability of performance: "job codification" and "rule observation." In any event, the incidence of standardizing devices with respect to the selection of course content was one procedure Keene used to bring his descriptive data to bear on the hypothesis that standardization increases with high school size/complexity. We have reproduced his table as our Table 1.

The second procedure involved judges' ratings of the extent of standardization in each of the 12 high schools (pp. 203-214). Keene condensed the materials he had obtained regarding the manner of selecting course content in the schools and put the brief, descriptive paragraphs on 5" X 8" cards. Eight judges were asked to rate the 12 descriptions on a graphic scale, identified at one end by the label "complete freedom" and at the other end by "complete limitation." The graphic scale had neither numbers nor intermediate designations. Judges were instructed to decide, in effect, what proportion of the process of selecting course content still remained a matter of the teacher's own choice in

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Table 1
SUMMARY OF THE PRINCIPAL STANDARDIZING DEVICES USED
TO COORDINATE INSTRUCTION IN TWELVE HIGH SCHOOLS*

Schools	Course title and textbook are specified	Little teacher influence on textbook adoption	Course outlines or curriculum guides are used	Little teacher influence on the nature of the guides or outlines	Teachers must cover specified materials	Deviation without permission is not permitted	The principal visits classes	Department chairmen visit classes	Teachers are rated	Salaries are contingent on the ratings	Semester-end tests are used	Daily lesson plans are required
1	X						X					
2	X											
3	X											
4	X											
5	X				X		X		X			X
6	X						X					
7	X		X				X	X				
8	X	X	X	X	X		X	X	X			X
9	X		X		X		X	X			X	
10	X		X		X	X	X	X	X	X		X
11	X	X	X	X			X	X	X	X		X
12	X		X		X	X		X	X		X	X

*From Keene (1962, p. 151).

each of the schools. The schools, incidentally, were identified only by a code letter on the cards. Keene derived raw scores by breaking the scale into 100 segments (100 representing "complete limitation") and noting the segments to which judges assigned the paragraph descriptions. Following Guilford (1954, pp. 280-288), the matrix of raw scores obtained from the ratings was corrected for "leniency" and "rater-trait interaction" errors, yielding an adjusted standardization score for each school. The same rating procedure was repeated for the other three dimensions (pupil evaluation, pupil discipline, and obtaining classroom supplies) using additional sets of descriptive paragraphs, but these data are less relevant to our present purpose and will not be reported. Based on judges' ratings, the adjusted scores for standardization in course content ranged from 9.5 to a high of 61.2 in the 12 high schools.

Relationships among Variables

Keene did not make an extensive examination of relationships among the quantitative measures described above. He simply reported correlations between high school enrollment and complexity ($r = .86$) and specialization ($r = .83$), demonstrated that mean standardization scores increase regularly in the four size-classes of high schools, and showed the greater incidence of standardization devices in larger than smaller schools (Table 1). The evidence sufficed to support his prediction that instructional standardization increases with school size and complexity.

We have carried the inspection of relationships somewhat farther. Product-moment correlations between the key variables are summarized in Fig. 3. All of these first-order coefficients are high, and with 10 degrees of freedom the small numerical differences among them are hardly worth interpreting. It is interesting, though, that standardization scores can be as readily predicted

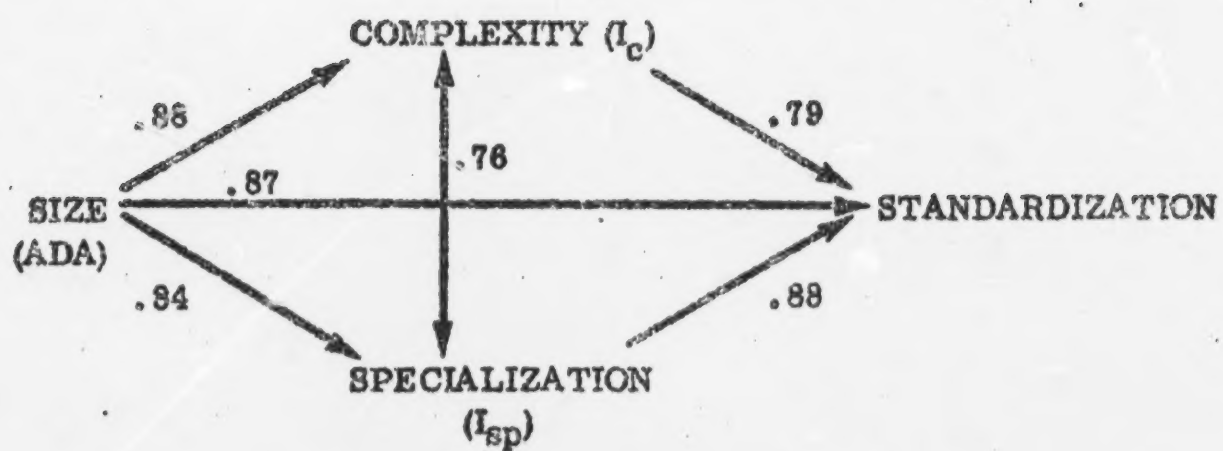


Figure 3. Product-moment correlations between key variables in Keene's study, 12 Illinois high schools.

from high school size (ADA) as from the two presumably intervening variables, complexity or specialization.

An important fact, however, cannot be seen in the summary correlations of Fig. 3: some of the relationships are strongly curvilinear. This is especially true of the ADA- I_c relationship, plotted in Fig. 4, where it can be noted that the rate of increase in complexity declines with increase in school size. When complexity is plotted against the log. of size, the relationship is approximately linear, and the product-moment correlation between log. ADA and I_c (corresponding to a curvilinear correlation coefficient) is nearly perfect, $R = .97$. Curvilinearity also appears in both components of I_c ; viz., I_h and I_v . (Treating the components as additive rather than multiplicative does not remove all the curvilinearity from I_c . Whatever the reason, it appears that an increase of, say, 500 students in small high schools markedly affects instructional complexity, but the same increase in large schools affects complexity only slightly.

The relationship between complexity and standardization is strongly curvilinear, too, but in a complementary fashion. The rate of standardization accelerates with increasing complexity. (See Fig. 5.) That is, a given increment in complexity in relatively uncomplicated (and generally small) high schools makes less of a difference in instructional standardization than it does in more complex (and generally larger) schools. The relationship is nearly linear between complexity and the log. of standardization. Using log. standardization the coefficient of correlation improves modestly--from .79 to .85.

The complementary character of these two relations might be regarded as strong support for the contention that complexity is an intervening variable between school size and standardization if complexity were expressed as an exponential value. Such a model would appear as follows:

ADA ——— (.97) ———→ e^{I_c} ——— (.85) ———→ Standardization,
 where e^{I_c} is the complexity index taken as an exponent of the base of the

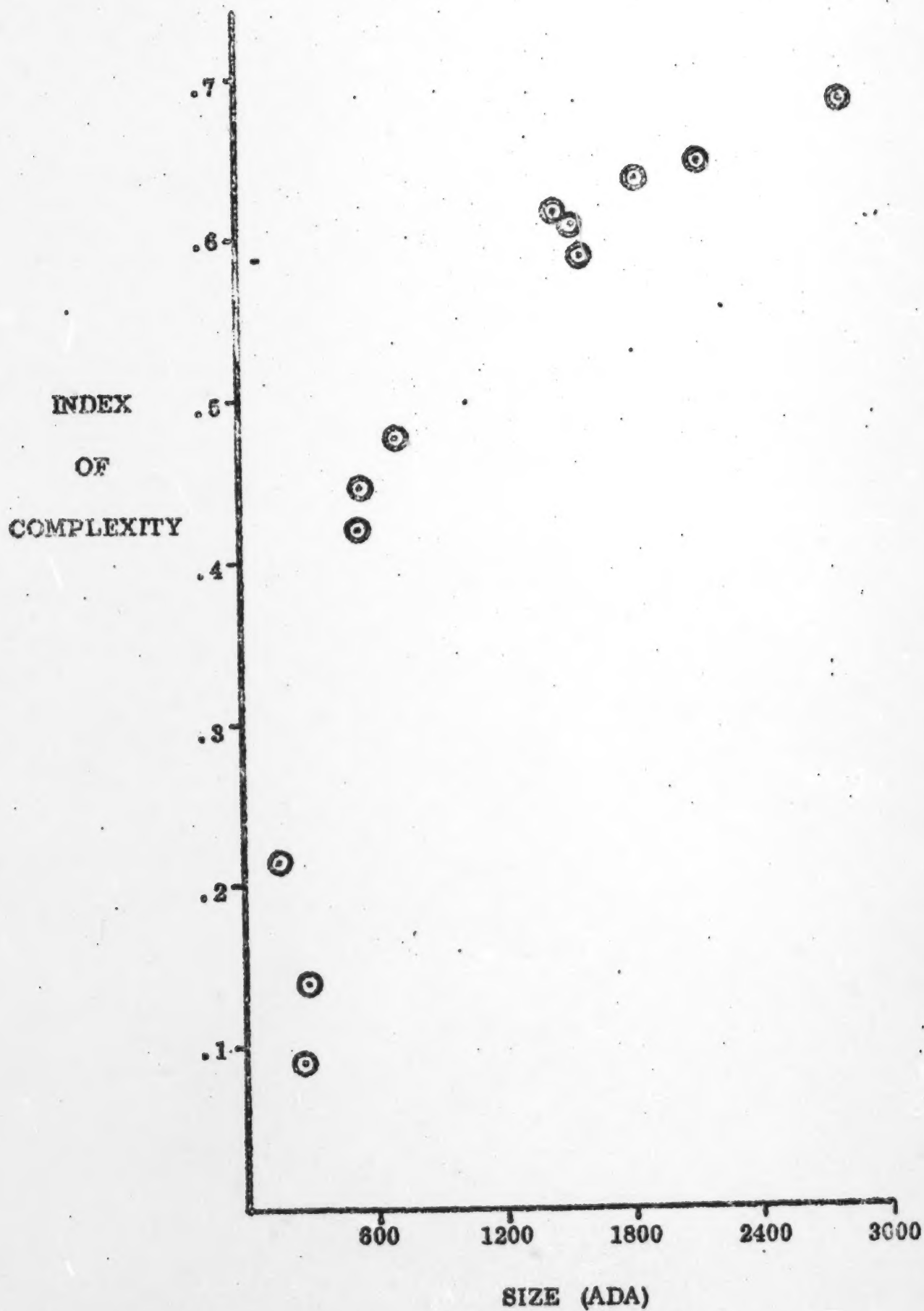


Figure 4. Complexity by high school size (Average Daily Attendance), 12 Illinois high schools.

STANDARD-
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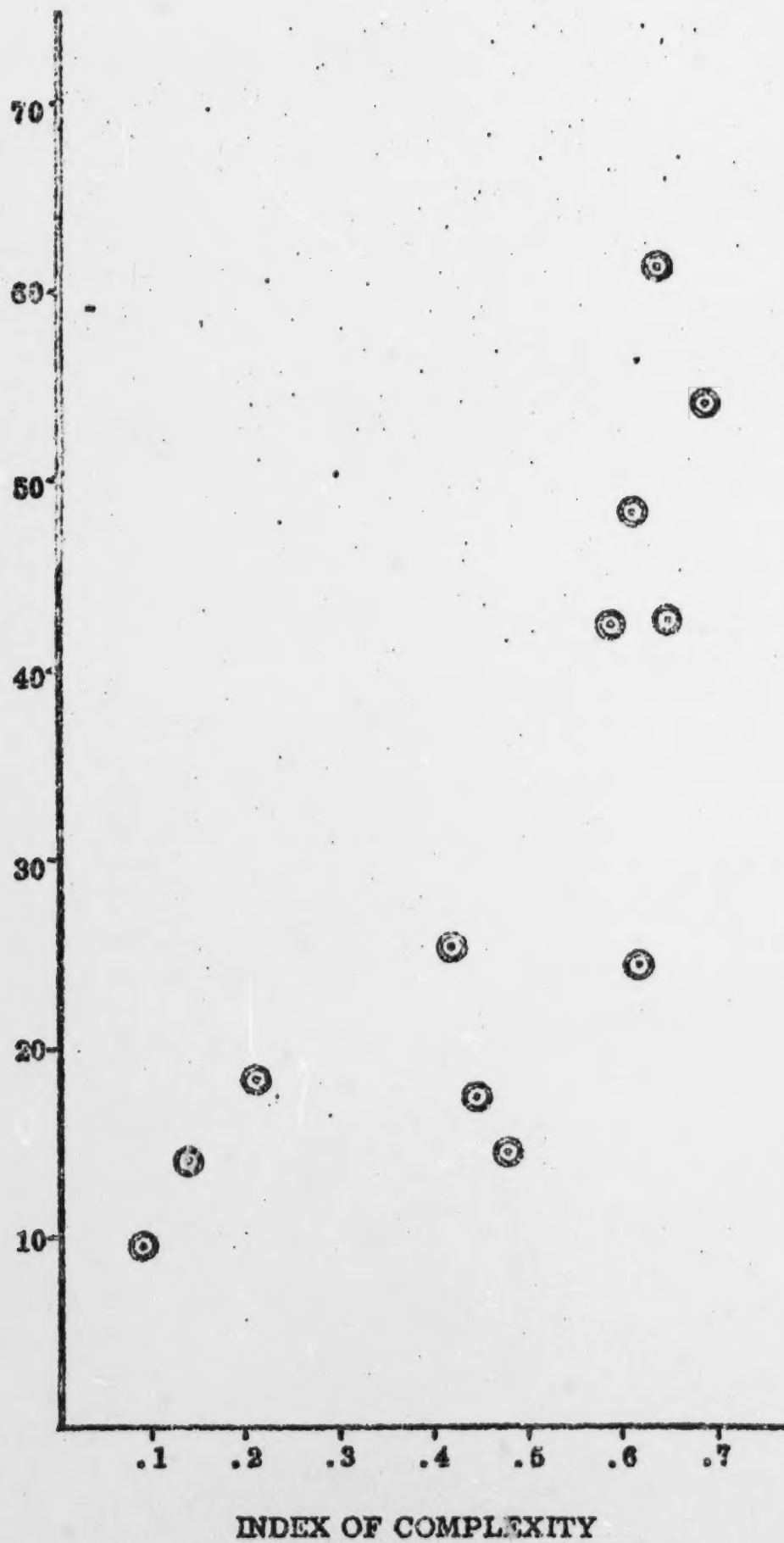


Figure 5. Standardization in course content by complexity, 12 Illinois high schools.

natural logarithms. The complementary form of the two relationships, on the other hand, may be an artifact due to the composition of the complexity index, which derives from ratios whose denominators are closely associated with school size--number of courses and number of sections of courses. In any event, the introduction of a rather intricate intervening variable does not seem to be a substantial improvement over the value of the direct linear relationship between ADA and standardization, $r = .87$.

The specialization variable behaves somewhat differently in its intervention between size and standardization. It is only slightly curvilinear in its relationship with ADA and does not become linear when plotted against log. ADA. In its relationship with standardization, the graph is linear when the log. of the standardization scores is used, and the correlation of .88 improves to .93 in curvilinear form. Thus, both I_{sp} and I_c are strongly dependent upon school size and both are closely associated with standardization.⁵ Disentangling the interrelations will require more elaborate statistical analyses than are justified here.

Keene gives us, then, a theoretical analysis of complexity in the division of instructional labor that is well articulated with a number of other important concepts of organization, an operational definition that is suitable at least to high schools and potentially to elementary schools, and a demonstration that the complexity index is very highly associated with several significant organizational variables as specified by the theory. There remain, however, important questions about the phenomena to which the variable is applied.

⁵None of our observations regarding curvilinearity nor the magnitude of correlations is appreciably altered if size of high school is measured by number of teachers rather than by ADA. The two size indicators are virtually interchangeable.

Commentary

As seen from the preceding account of empirical studies, considerable variation exists in the meaning and measures of complexity. Perhaps the most serious shortcoming, though, is that few of the writers point out what it is that is taken to be more or less complex. Complexity is an attribute of something, but only Udy and, more especially, Keene provide suggestions as to what that something is. In a formal sense, complexity refers to some property of the interconnections among a set of elements. What are the elements in the set--work operations for Udy, units into which the workflow is broken for Keene--and what is the nature of their connections? Investigators have spent little effort in considering these questions.

If we turn away from empirical studies of organizational complexity to more general treatments or to some other social science fields, we find more satisfactory discussions of the concept. Cognitive psychologists following the work of Kurt Lewin, for example, have sought to specify systematically the various structural properties, including complexity, by which cognitions can be conceptualized and measured. Zajonc's (1960) definitions are probably the most rigorous. Paraphrased, they include:

Degree of differentiation--the number of distinct elements that comprise the set.

Degree of complexity--the number of classes of discriminanda according to which the elements are differentiated.

Degree of unity--the extent to which elements of the set depend on (or, obversely, determine) one another.

Degree of organization--the extent to which the unity of the set is dominated by a single element.

Scott (1963, pp. 277-278) has argued persuasively that differentiation and complexity in Zajonc's definitions are so intimately related that they amount to the same property. We believe that it is possible, in principle, to maintain

Zajonc's distinction between differentiation and complexity in the case of educational organizations, but this would yield a definition and measure of complexity far removed from any that is conventionally employed in the organizational literature. In that literature, complexity and degree of differentiation are virtually synonymous.

Small groups theorists, in their conceptualizations of group problem-solving research, have addressed themselves to the nature of the interdependencies that arise among members of groups as they attempt to solve the assigned problems. Tasks differ markedly in the kinds of interdependency they impose. Thibaut and Kelley (1959) offer a fruitful mode of analyzing the contingencies that one person's behavior introduces for the behavior of a second person. They distinguish two general ways in which members of a group at work on a problem are locked into a system of interdependency: (1) through their concerns with how the outcomes of the task are distributed among the members, and (2) through the demands the task itself imposes on how members must respond, or act, in order for any good outcomes to be forthcoming. Recently they have extended their analysis to a third mode of interdependence, viz., information dependence (Kelley & Thibaut, 1969).

Differences in outcome distribution helps to separate "cooperative" from "competitive" task conditions, a conventional comparison made in group problem-solving experiments. A cooperative task is one in which there is a high correspondence in outcomes for the two (or more) group members. "The task requirements they must meet in order to achieve A's best outcomes are identical with the requirements to be met for B's best outcomes (Thibaut & Kelley, 1959, p. 165). A competitive task, then, is one in which there is noncorrespondence of good outcomes. In the authors' matrix presentation of A's and B's net outcomes from each party's available behaviors, the nature of the outcome distribution can be displayed concisely.

Conditions of the task may also vary in how participants must behave, or respond, to obtain any good outcomes at all--i.e., to complete the task or solve the problem. A conjunctive task requirement entails that all members of the group make an appropriate response. It need not be the same response, although it would if successful task completion required that the members reached consensus on the solution. The task could be broken into component parts, as in a division of labor, and each member would make a distinctive response. If successful task completion required all members to make a distinctive response, it would be classed as a conjunctive requirement. A disjunctive task requirement, on the other hand, entails only that some member of the group, any one participant, make the appropriate response. The import of this distinction is that where a disjunctive task permits participants to work independently without communication or coordination, a conjunctive task requires that they communicate with one another and coordinate their efforts.

Thompson (1967), an organization theorist, provides some further concepts. The three forms of interdependence he specifies elaborate on Thibaut and Kelley's conjunctive task conditions. Pooled interdependence, the simplest form, is the situation in which each participant can render a discrete contribution to the task--a rather loose form of the division of labor. Under sequential interdependence, responses of the participants must be given in a particular order. Thus, A must act appropriately before B can act. Whyte's (1948) description of the flow of food orders in the restaurant well illustrates such a system of assymetric interdependence. The most complex form is what Thompson calls reciprocal interdependence and refers to the situation in which A's performance is required for B to act and B's action is required for A's appropriate behavior. The outputs of each become the inputs for the other, in a symmetrical manner. These three forms, according to Thompson's conception,

constitute a cumulative scale: the more complex forms imply the existence of the less complex forms. Our use of "complex" in the preceding sentences, incidentally, is not accidental. Thompson defines complexity of work processes precisely in terms of the order of interdependence they demand.

Thompson's analysis of interdependence led him to examine devices for achieving coordination and, like Keene (1962), drew on the work of March and Simon (1958) to do so. Thompson described coordination by standardization, by plan, and by mutual adjustment. These devices specifically parallel the three forms of interdependence.

With pooled interdependence, coordination by standardization is appropriate; with sequential interdependence, coordination by plan is appropriate; and with reciprocal interdependence, coordination by mutual adjustment is called for (Thompson, 1967, p. 56).

The types of coordination, in the order listed, place increasingly heavy burdens on communication and decision and, as Thompson goes on to show, affect the shape that an organization assumes.

The educational literature contains few detailed accounts of how the school's tasks are interlinked. Atwood (1964) dealt with a narrow sector of the problem in his descriptions of changing interaction patterns associated with the centralization of guidance activities in a large, urban high school, and Pellegrin (1969) described the kinds of people on whom elementary teachers said they depended in their work in a number of schools. We have seen, too, that Keene discussed the dependence of sequenced courses in high schools (his "vertical complexity") and the dependence between sections of the same course ("horizontal complexity"). These could refer to sequential and reciprocal interdependence, respectively, but Keene's analysis was based on assumptions about the contingencies posed, not on actual observation of them.

Some analysts of American public education doubt that anything other than the most gross interdependencies exist in the technical system of the school. The school has been characterized in terms of its "structural looseness," and

autonomous teachers in self-contained classrooms is often noted as a cardinal feature of educational organizations (Bidwell, 1965). In a rough way, of course, the school is a cooperative enterprise. A general sort of correspondence of outcomes exists among school personnel, such that each participant reaps the rewards of participating in a well-regarded (and well-supported) educational system. But the means-end connection between the instrumental acts of each participant and the public support accorded the enterprise is hardly transparent, especially considering the number of participants in the school and the uncertainties indigenous to the processes of instruction.

From the standpoint of response interdependencies, there is reason to suspect that they reside more strongly in school operations that are incidental to its core task of instruction than in the instructional task itself. In an earlier article (Charters, 1964), we acknowledged that sequential interdependence can be found in the educational institution with respect to the teaching-learning process but mainly it is of a remote variety.

What the teacher hopes to teach his pupils is often contingent upon their having learned something earlier. This is most obviously the case in connection with the "tool" subjects. It would be extremely difficult for a high-school science teacher to succeed in inducing expected changes in students who, in earlier years, had failed to learn to read. It is also assumed to be the case in the so-called cumulative subjects. Capacity to profit from "Spanish II" depends upon skills acquired in "Spanish I"; plane geometry may be said to depend upon the concepts and skills acquired in algebra (p. 256).

Beyond this level, interdependencies in the instructional process begin to fade.

"Horizontal" as well as longitudinal contingencies are sometimes regarded as important. The elementary-music teacher's instruction may be designed to supplement and reinforce objectives of the grade teacher; objectives in the general science course may relate to those of the civics course. We are led to believe, however, that many of these longitudinal and horizontal contingencies are more matters of traditional assumption than evident fact (p. 256).

It has occurred to us that the carefully planned curricular programs in high schools (and universities, too), with their foundations courses, prerequisites, course sequences, and the like, are designed with an eye more to managing the traffic flow of students and logistical problems of space and manpower allocation than to pedagogical necessity.

In the same article, we suggested several tangential areas where contingencies in work may be especially strong: in the timing of movements in the school, in classroom management practices, and in the use of scarce instructional resources, such as buses, projectors, playground space, and so on.

The fact remains, however, that discussion of the task interdependencies in schools is largely speculation. First-hand observations, as we noted, are rare. It would seem that a fully meaningful measure of complexity in the school's technical system will require, first, closely detailed analyses of the work operations and their interconnections.

Appendix A

A Note on Specialization

Although specialization and division of labor are often used synonymously, the former concept carries additional psychological meaning when put to theoretical use or even when employed as a common-sense term. Specialization implies that a person who undertakes a sub-divided task can, by virtue of training and/or continued attention to it, develop a competency in its performance beyond that of a non-specialist. This, in turn, implies a particular pattern of manpower allocation under a division of labor, such that personnel are assigned to parts of tasks on a reasonably permanent and exclusive basis. An identical division of labor can produce specialists or jack-of-all trades, depending on the allocation pattern. Thomas and Biddle (1966) extend the analysis further. It is also the case that some bases for dividing tasks are more conducive to the development of unique competencies in the sub-parts than other bases.

An operational indicator of specialization, then, is the extent to which participants in a division of labor are not interchangeable among the sub-tasks without sacrificing competent performance or, at least, the extent to which they are regarded as not interchangeable. This, in more general terms, is the grounds for Keene's measure. His situation was simplified by the fact that teacher certification standards codify beliefs about the interchangeability of high-school teachers between "subject areas."

Our more general definition of specialization permits its use as a continuous variable rather than as an attribute. It also enables us to apply it to the elementary school, where the division of labor customarily is based on age-grade lines rather than subject-matter lines. We can ask, with regard to the elementary school, in what degree (and among what grades) are teachers not seen as interchangeable. From this perspective, specialization is low at

the elementary level inasmuch as a) training programs tend to be undifferentiated by grade-level, b) certification standards similarly are undifferentiated, and c) assignment practices assume a high degree of interchangeability. At the same time, one can observe in both training programs and assignment practices a tendency to differentiate between the primary grades and intermediate grades, so that specialization is not entirely absent.

We propose that the difference in the degree of specialization between elementary and secondary schools rests upon differences in the knowledge base undergirding the parts into which instructional labor is divided. Given current knowledge regarding learning, motivation, and child development, it is unlikely that unique instructional competencies soon will be required to teach 5th-grade children that are distinct from those required to teach 6th-graders. Developmental psychology could reach a point, however, that it dictates marked differences in instructional practice for students at varying stages of cognitive or social-emotional growth. Meanwhile, a division of labor organized around subject-matter, as in the secondary school, virtually assures a higher degree of specialization and will continue to as long as it is accepted that teachers need to know something about the subjects they teach as well as the children they teach. Considering the limitations in time and human capacities, teachers are unlikely to develop as high a competency in teaching mathematics and world history and French as they would were they to specialize in any one.

Appendix B
Major Subject Area Divisions*

Major Subject Area Divisions	"A" (Limit-One)	"B"
<u>English</u>	English Grammar, Reading, Literature, Any Course Titled "English" Including Business English	Speech Journalism
<u>Mathematics</u>	All Mathematics Courses Including Business Mathematics	
<u>Physical Science</u>	Physics, Chemistry, Astronomy, Air Science, General Science	
<u>Life Science</u>	Biology, Zoology, Botany, Geology, Health, Physiology, General Science Conservation	
<u>Social Studies</u>	History, Problems, Economics, Government, Civics, Social Studies, Social Science, Geography, Sociology, Psychology	
<u>Art</u>	Drawing, Painting, Design, Sculpturing, Pottery, Weaving, etc.: All Courses Titled "Art"	
<u>Music</u>	All Vocal Music All Instrumental Music Music Appreciation	
<u>Foreign Language</u>		Any (one) Foreign Language (e.g., Latin, French, Spanish, German, Russian, etc.)

*From Keene (1962, pp. 55-56).

Appendix B (Continued)

<u>Commerce or Business</u>	Typing, Shorthand, Bookkeeping, Secretarial Practice, Office Practice, Commercial Law, Distributive Education	
<u>Home Economics</u>	All Homemaking Courses, All Home Economics Courses, Family Living, etc.	
<u>Agriculture</u>	All Agriculture Courses, All Agriculture Shop Courses, Conservation	
<u>Shop</u>	Drafting, Electricity, Metal, Wood, All Industrial Arts Courses	The Building Trades, Other T&I Courses, Diversified Occupations
<u>Physical Education</u>	Physical Education, Health, Physiology, First Aid	
<u>Driver Education</u>	Driver Education, Behind-the-Wheel Driving, Safety, First Aid	
<u>Guidance</u>	Counseling, Testing Teaching Courses in Personality, Adjustment, Vocations and Occupations, and the like	
<u>Library</u>	No Teaching Except Library Science	

For a teacher to be counted as a "specialized teacher" and thus placed in the numerator of the Specialization Index, he may teach any or all the subjects listed in Column "A" for any one (but only one) of the major subject divisions.

He may also teach one (but only one) of the subjects listed in column "B" for the same major subject area division in which the other teaching is classified.

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